Making Cars Drive Themselves
1988-1991 DARPA ALV Program
1991-2003 Demo I – III Programs (ARL+DARPA)
2001 Congress mandates: A third of all ground vehicles unmanned by 2015
2001-2004 DARPA Perceptor
2001-today: Army’s “Future Combat Systems
  – 10mph
  – frequent human intervention

2003 DARPA creates Grand Challenge
  – Up to 60mph
  – no human intervention whatsoever
  – no funding, but million dollar price
Grand Challenge 2004: Barstow, CA, to Primm, NV

- Natural and manmade hazards
- No driver, no remote control
- No dynamic passing
- Fastest vehicle wins the race (and million dollar prize)
Grand Challenge 2004: 106 Teams

[Map of robotic teams across the United States with locations and names of teams listed.]
2004 DARPA Grand Challenge
Result 2004: All robots fail in first 5% of course
Stanford CS294 “Projects in AI”
Volkswagen Donates A Car
Drive-by-Wire System
Stanley: Sensor & Computers

- 5 Lasers
- Camera
- Radar
- GPS compass
- 6 Computers
- IMU
- E-stop
- Control Screen
- Steering motor
Steering Control

Cross-Track Error

Steering Angle (with respect to trajectory)

Velocity

Reference Trajectory
Following GPS Waypoints
Laser Sensor

© Popular Mechanics
Road boundary

$\delta$ lateral offset

Sebastian Thrun, Stanford University
Dec 1, 2004, near Barstow, CA

First Autonomous Desert Mile
Problem Solved?
Probabilistic Error Model

\[
\text{trigger if } |Z_i - Z_j| > 15 \text{cm for nearby } z_i, z_j
\]
Without Probabilities: 12.6% false positives

With Probabilities: 0.02% false positives
How Fast is Fast Enough?
How Fast is Too Fast?
Manual Driving

Offroad Testing

Stanford Racing Team

Sebastian Thrun, Stanford University
Speed Limit
Human Driving
Velocity Planner
Grand Challenge 2005: 195 Teams

New Team (160)

2004 applicant (35)

Not Shown: Autonomys, West Coast Robotics and UBC-CERES Team Thunderbird -- Canada,
Grand Challenge New Zealand, Dotmobil Team -- France,
Carnegie Mellon “Red Team”

- Top speed 50mph (?)
- Longest single run: 200 miles
Ripsaw II
Promo

Approx. run time: 6 minutes
Axion Racing
Cal Training Videos

UC Berkeley
National Qualification Event
The Grand Challenge Race
City Driving

- Robotic and human traffic
- Sequence of goals
- Speed: 30mph max
- Rules: CA Traffic Law
- DARPA provides map (RNDF)
Urban Challenge 2007
The Urban Challenge Event
Problem Solved?
Technology Spinout
Sebastian Thrun, Stanford University
Big Picture
Traffic Accidents
  - 42,000 dead every year (USA)
  - 2,700,000 injured (USA)
  - Leading cause of death, age 3-33

Commuting
  - 1.25 hours per day (USA)

Let Everyone Drive!
  - Blind people, elderly, kids
  - Without driver (self-parking car, car sharing)

Energy
  - 22% of Nation’s energy used by cars
  - Convoys reduce energy consumption by 11%-17%

Highway Congestion
  - 3% annual increase of highway use (USA)
  - New highway construction at all time low